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Effect of Misting on Water Loss, Growth, and Mycorrhizae in Engelmann Spruce and Douglas-fir

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SUMMARY

Short duration applications of fine-droplet water mist were applied at frequencies of 20 or 30 minutes to container-grown Engelmann spruce and interior Douglas-fir for 17 days when maximum daily air temperature exceeded 30° C. Water loss from containers, seedling growth, and mycorrhizal colonization were assessed.

Applying mist every 30 minutes during mid-day did not alter water loss of spruce ($P=0.47$), but average daily weight loss of misted Douglas-fir was 22% greater ($P=0.06$) compared to that in non-misted trees. Water loss of spruce and Douglas-fir was decreased ($P=<0.01$) when mist was applied every 20 minutes.

Compared to non-misted spruce, misted trees had shorter shoots ($P=0.03$), smaller shoot:root ratios ($P=<0.01$), and greater root weight ($P=<0.01$), total seedling weight ($P=0.08$), and Dickson Index ($P=<0.01$). Misting did not alter growth of Douglas-fir.

Mycorrhizal colonization of spruce roots by *Thelephora terrestris* decreased ($P=0.09$), while *Amphinema byssoides* increased ($P=0.08$) in misted relative to non-misted seedlings. Differences in growth between misting treatments of spruce likely resulted from greater colonization of misted trees by *Amphinema*. Mycorrhizal colonization of Douglas-fir was not affected by misting.

Repeated, short duration misting of Engelmann spruce and interior Douglas-fir during hot weather can be used to reduce water loss by up to 36% from styroblock containers. Misting may indirectly alter growth of spruce by affecting mycorrhizal colonization. When applied properly, misting does not increase the risk of foliar disease.

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INTRODUCTION

Misting is used in some container nurseries to cool shoots during hot weather. While no data have been collected to document its effects on growth or water loss from container-grown seedlings, some growers feel it is a beneficial water management practice when used properly.

High summer temperatures in the southern Interior of British Columbia necessitate frequent watering of container-grown conifer crops. However, repeated saturation watering may result in poor aeration and inadequate oxygen supply in the root zone. Indications of poor root system aeration are not uncommon in southern Interior nurseries, where varying degrees of lenticel hypertrophy, apical foliage spiralling, root swelling ("water roots") (Langerud and Sandvik 1987), and suppression of feeder root development have been noted (G. Hunt, unpublished data). Growth of mycorrhizal fungi in container root plugs, whether these have been inoculated intentionally or naturally, is strongly inhibited by inadequate oxygen supply (Gadgil 1972; Read and Armstong 1972). These fungi are important to the development of feeder roots, through the production of hormones which substantially increase root branching (Slankis 1973).

Improving root system aeration can be approached experimentally in three ways: 1) by altering the material or design of containers; 2) by changing the growing medium; or 3) by slowing the rate of water loss from containers, thereby increasing the interval between saturations. This study examined the latter. The objectives were to determine: if misting can be used to reduce the rate of water loss from containers; if misting repeatedly for short duration will induce foliar disease; and if misting affects seedling growth, mycorrhizal colonization, or tissue nutrient status.

METHODS

Seed from B.C. Forest Service registered Engelmann spruce (*Picea engelmannii* Parry) seedlot 27133, and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) seedlot 26227 were sown at the Heffley Reforestation Centre Ltd. nursery (lat. 50°51' N, long. 120°16' W) in March 1987, in PSB 313a styroblocks (198 cavities per block, 947 cavities per square metre.[1] The growing medium was composed of peat and vermiculite (4:1, v:v) with dolomite lime. Nutricote (16-10-10) Controlled Release Fertilizer[2] was incorporated at a rate of 1.9 kg/m^3 in the spruce medium.

Soluble fertilizer was applied according to the following schedule: Peters Conifer Starter (7-40-17)[3], was applied over 5 weeks at an average rate of 28 ppm N; Peters Conifer Grower (20-17-19) was applied for 8 weeks at 100 ppm N; and Plant-Prod Finisher (8-20-30) Forestry Seedling Finisher[4] was applied for 12 weeks at 50 ppm N. All treatments received the same amount of soluble fertilizer over the growing season. Except for misting, treatments within tree species were irrigated equally throughout the growing season.

Seedlings were reared in a double polyethylene-covered greenhouse until the second week in June when the cover was removed for the remainder of the growing season. Photoperiod was extended to 18 hours until June 29 through the use of high pressure sodium lamps.

Mist was applied during 17 days (non-consecutive) in July and August. With one exception, misting was done only on days when maximum air temperature was ≥ 30°C . Misting nozzles had tips delivering 0.27 L/min. through a 100 mesh screen at 207 KPa (30 psi) of pressure. The computer-controlled irrigation boom operated between 11:00 a.m. and 4:00 p.m. applying mist over half the greenhouse area with one pass of the boom. This was sufficient to wet the upper portion of the canopy, but not drip onto the surface of the growing mix. Before misting, all containers were irrigated to saturation and allowed to drain until water drops were no longer present at the base of cavities. Successive saturation watering was based on average block weights suggested by the Ministry of Forests. Frequency of misting was changed from 30 to 20 minutes approximately half way through the study. Ten randomly selected

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1 Manufactured by Beaver Plastics, Edmonton, Alta.

2 Manufactured by Chisso-Asahi Fertilizer Co. Ltd., Tokyo, Japan.

3 Manufactured by W. R. Grace Co., 62 Whittemore Ave., Cambridge, Mass., 02140.

4 Manufactured by Plant Products Co. Ltd., 314 Orenda Rd., Brampton, Ontario, L6T 1G1.

containers for each of four treatments (misted and non-misted, Engelmann spruce and Douglas-fir) were marked and re-weighed at each measurement. Selected containers were weighed two or three times (at approximately 11:00 a.m., 1:00 p.m., and 3:00 p.m.; or at 11:00 a.m. and 3:00 p.m.) on each of 10 days.

Samples for assessing growth consisted of 50 trees selected randomly from each treatment (the outer two rows of trees in a sampled container were excluded to remove edge effects). Shoot length and root collar diameter were recorded, seedlings were separated at the root collar, dried at 100°C for 24 hours, and weighed. The Dickson Quality Index (dry weight / [height:diameter ratio + shoot:root ratio])was calculated as a measure of seedling balance (Dickson *et al.* 1960a, 1960b).

Degree of mycorrhizal colonization was determined on a random subsample of 10 trees per treatment. Root systems were soaked in water over night and gently washed under running water to remove the growing substrate. To assess each seedling, the entire root system was inspected under a dissecting microscope (2-10x). All of the highest-order lateral roots were divided into ectomycorrhizal and non-mycorrhizal groups based on morphological characteristics, such as presence of a fungal mantle, bifurcation, diameter, or absence of root hairs (Wilcox 1982). Data were expressed as mycorrhizal density, that is, the estimated percentage of highest-order lateral roots ("feeder roots") that were mycorrhizal.

Data were subjected to analysis of variance and the F test was used to separate treatment means.

RESULTS

Analysis of data within each misting frequency (Table 1) showed that weight loss among misting treatments in spruce did not differ (P=0.47) at a misting frequency of 30 minutes. Average weight loss of misted Douglas-fir was greater (P=0.06) compared to that in non-misted trees during the 30-minute frequency period. Water loss from misted containers, relative to non-misted, was highly significant at the 20-minute frequency for both species . Figure 1 shows an example of weight loss over 2 days, comparing misted and non-misted spruce.

Misting did not alter growth of Douglas-fir (Table 3), but it did affect growth of spruce (Table 2). Total seedling dry weight and root weight were greater in misted than in non-misted trees, while shoot height and shoot:root ratio were reduced in misted trees. Difference in overall seedling balance between treatments resulted in an improvement ($P < 0.01$) in the Dickson Index.

The effect of misting on mycorrhizal colonization of spruce was also determined (Table 4). Colonization by *Thelephora* was higher in non-misted (P = 0.09) than in misted trees, and the amount of *Amphinema* was substantially greater (P = 0.08) in misted trees. Percentage of non-mycorrhizal and E-strain colonized roots did not differ between treatments. Colonization of Douglas-fir was uniform among treatments.

Standard tissue nutrient analysis[5] of 12 elements indicated that all except three had reasonably similar concentrations comparing misted and non-misted treatments of both tree species. Iron, sodium, and boron appeared to be higher in misted treatments of both species, although single sample testing precluded statistical analysis. In both treatments, levels of these elements were within standard acceptable ranges.

DISCUSSION

Water Loss

Temperature affects the rate of transpiration and was likely a major factor influencing water loss in this study. A temperature of 30°C was established arbitrarily as the minimum for applying mist. This ensured rapid evaporation of mist droplets from needles and minimized risk of moisture-induced disease.

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5 Conducted by Chemac Industries Inc., #11-368 Industrial Ave., Kelowna, B.C. V1Y 7E8.

TABLE 1. Average weight loss of containers and results of analysis of variance for misted and non-misted Engelmann spruce and Douglas-fir at two misting frequencies[a]

Tree	Misting frequency (Minutes)	Mean hourly weight loss (g)		MSE	F	P
		Misted	Non-misted			
Spruce	30	178	194	9928	0.52	0.47
	20	65	88	1933	8.50	<0.01
Douglas-fir	30	101	83	1697	3.66	0.06
	20	92	143	2435	32.73	<0.01

[a] Degrees of freedom are 1 and 78, and 1 and 118 for the 30- and 20-minute frequency, respectively.

TABLE 2. Seedling growth and results of analysis of variance for misted and non-misted Engelmann spruce[a]

	Misted	Non-misted	MSE	F	P
Shoot height (cm)	24.26	25.77	11.65	4.89	0.03
Stem diameter (mm)	3.02	3.07	0.14	0.54	0.46
Shoot weight (g)	1.89	1.88	0.18	0.04	0.85
Root weight (g)	0.82	0.63	0.05	19.30	<0.01
Total weight (g)	2.71	2.50	0.34	3.14	0.08
Shoot:root ratio	2.38	3.25	0.70	26.64	<0.01
Dickson Index	0.27	0.22	0.01	10.52	<0.01

a Degrees of freedom are 1 and 98.

TABLE 3. Seedling growth and results of analysis of variance for misted and non-misted Douglas-fir[a]

	Misted	Non-misted	MSE	F	P
Shoot height (cm)	24.18	24.46	7.65	0.26	0.61
Stem diameter (mm)	2.97	2.88	0.17	1.24	0.27
Shoot weight (g)	1.71	1.64	0.13	1.13	0.29
Root weight (g)	0.92	0.89	0.05	0.34	0.56
Total weight (g)	2.63	2.53	0.30	0.91	0.34
Shoot:root ratio	1.89	1.92	0.14	0.16	0.69
Dickson Index	0.27	0.25	0.01	1.68	0.20

[a] Degrees of freedom are 1 and 98.

TABLE 4. Percentage of mycorrhizal and non-mycorrhizal feeder roots and results of analysis of variance for misted and non-misted Engelmann spruce[a]

	Misted	Non-misted	MSE	F	P
Non-mycorrhizal	17.5	32.9	659	1.80	0.20
Thelephora terrestris	16.9	40.5	868	3.21	0.09
Amphinema byssoides	57.5	25.9	1,465	3.41	0.08
E-strain	8.1	0.7	320	0.86	0.37

[a] Degrees of freedom are 1 and 18.

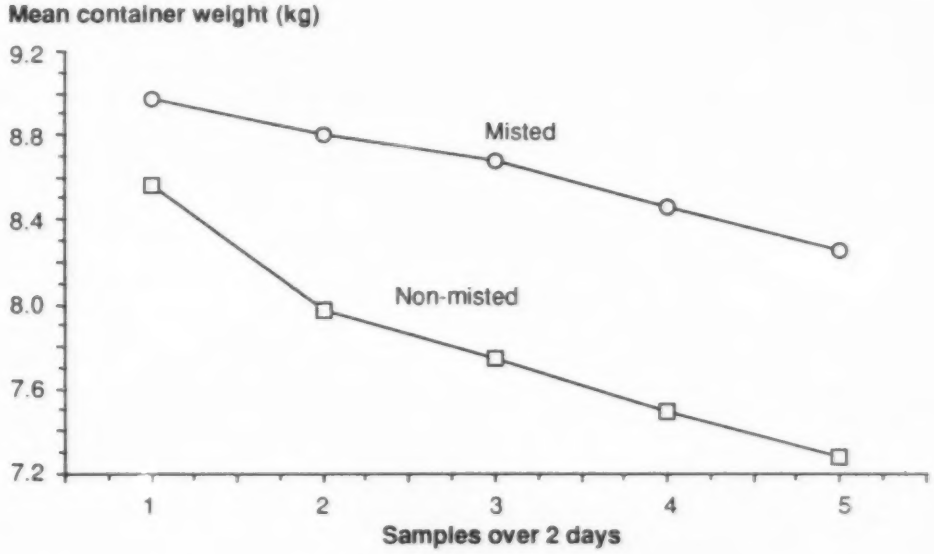

FIGURE 1. Average weights of misted and non-misted Engelmann spruce containers over 2 days.

Thirty-year weather records for Kamloops indicate an average of 29 days annually when maximum daily temperature is ≥ 30°C. The summer of 1988 was near normal with 32 days in this temperature range.

Comparison of maximum daily air temperature with water loss showed no significant correlation. Although more data may have revealed a relationship, it is likely that other factors influencing transpiration would preclude temperature being used to predict water loss. Light level, humidity, air currents, and available soil water interact with air temperature to determine transpiration rate.

Average weight loss of non-misted Engelmann spruce was greater, relative to that in misted trees, regardless of misting frequency (Table 1). The difference, however, was significant only for the 20-minute misting frequency. This supports the hypothesis that longer exposure to moisture with alternating dry periods decreased stomatal opening and suppressed transpiration. Greater weight loss of misted Douglas-fir suggests that the degree of stomatal opening and transpiration were increased by misting every 30 minutes. For both tree species, transpiration was clearly inhibited by misting under the 20-minute frequency regime.

Table 1 indicates that misting can either increase or decrease transpiration. The ultimate driving force responsible for transpiration is the vapor pressure gradient between the interior and exterior of the needle.

This gradient is determined by a combination of canopy microclimate factors (see above). Without measuring these factors, definitive explanations of water loss recorded in this study cannot be made.

Growth and Fungal Colonization

Decreased shoot height and increased root weight recorded in misted compared to non-misted spruce resulted in a substantial decrease in shoot:root ratio and increase in the Dickson Index in mist-treated trees (Table 2). Shorter height was most likely a consequence of greater colonization of misted trees by the mycorrhizal fungus *A. byssoides* (Table 4). Some strains of mycorrhizal fungi reduce seedling height (Molina and Chamard 1983; G. Hunt, unpublished data) by diverting photosynthate for their growth. *Amphinema* also produces dense accumulations of hyphae and rhizomorphs throughout root plugs and increases the dry weight of roots relative to root systems not colonized by this fungus (G. Hunt, unpublished data). This is the most likely explanation for the greater root weight of misted spruce. If differences in height and root weight resulted from *Amphinema*, then misting was not the direct cause of altered growth and the effect is not likely to recur regularly unless other conditions affecting establishment of *Amphinema* remain favourable (see below).

Greater weight of misted compared to non-misted spruce suggests that misted seedlings had either lower respiration or increased photosynthesis. *Amphinema* produces substantially more extramatrical hyphae and rhizomorphs than does *Thelephora*. It follows that misted seedlings, with more *Amphinema*, may have a higher respiration rate, or at least one not substantially less than that in non-misted trees. Greater net photosynthesis of misted trees may have resulted if misting allowed stomata to remain open with a low transpirational flux (D. Lavender, University of B.C., pers. comm.).

No consequential interaction between misting and growth of Douglas-fir was established (Table 3), although, comparison of treatment means for shoot height, root weight, total weight, shoot:root ratio, and the Dickson Index showed the same general trends as for spruce. All Douglas-fir were uniformly colonized by an unidentified mycorrhizal fungus. Interior Douglas-fir is generally colonized by this symbiont at the Heffley nursery and perhaps throughout the southern Interior.

Difference in fungal colonization on spruce by *Thelephora* and *Amphinema* (Table 4) appears to be an effect of misting, although an explanation is not readily apparent. Fungal colonization is affected by numerous factors, including total amount and concentration of applied fertilizer, aeration in the root zone, and tissue nutrient status. Root zone aeration appeared adequate in both treatments. Both swollen roots and inflated root lenticels, indicators of oxygen stress, were absent. Furthermore, tissue nutrient levels did not differ substantially among treatments at the end of the growing season. Nine of 12 measured elements were within the currently accepted range; nitrogen, calcium, and sulphur were slightly below minimum in all treatments.

Thelephora is the most common mycobiont in conifer nurseries and has a relatively high tolerance for soluble fertilizer. As a poor competitor, however, it is readily displaced by other fungi when conditions in the growing medium permit. Clearly, one or more factors differed between the misting treatments that influenced colonization, but the available data cannot establish which factors were involved or how they were related to the treatments.

Because mist was applied over only 17 days of the growing season, it seems unlikely that growth differences in spruce were a direct result of misting. That growth of Douglas-fir was not affected by misting further supports this conclusion. A second study is required to clarify this effect.

Disease

No visible signs of disease appeared in either misted or non-misted trees. Because mist droplets were allowed to evaporate completely before the next mist application, there is no reason to suspect that canopy fungal disease would increase, even if misting were carried out for a month or longer. Careful attention must be given to proper application of mist. Penetration into the canopy must be limited to the upper two-thirds to three-quarters to allow complete evaporation before the next misting pass. Droplets must not drip into the canopy base or growing medium. *Botrytis* is the only notable foliar disease at the Heffley nursery. It generally starts growth at the canopy base late in the growing season as day length shortens, air temperature decreases, and dew settles on the shoots. The disease does not appear to develop when misting is carried out during hot weather.

Future Study

With the evidence that water loss is affected by misting, additional information should be gathered in succeeding studies. Data on how misting affects canopy temperature and humidity would likely help explain the differences in water loss recorded in this study. As well, measurement of needle conductance would indicate the effect of misting on stomatal function. Evaporation can be quantified by the Penman-Monteith equation (Jones 1983). This would require estimates of available energy and needle conductance derived from measurements of canopy microclimate factors such as air temperature, humidity, and duration of sunlight.

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